Results of Ohio River Biological Monitoring During the 1988 Drought[1]

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Abstract
The Ohio River Ecological Research Program is a long-term monitoring study sponsored by several electric utilities owning coal-fired power plants on the Ohio River (American Electric Power, Cincinnati Gas & Electric Company, Ohio Edison Company, Ohio Valley Electric Corporation, Tennessee Valley Authority). The 1988 drought created anomalous physicochemical conditions in the Ohio River; extremely low flows and elevated ambient water temperatures were observed at plant sites between RM 54-946. Despite potential limiting conditions, monitoring studies indicated diverse and healthy communities. Macroinvertebrate data indicated no consistent differences between upstream/downstream assemblages; substrate quality appeared to be more limiting than water quality at all plant sites. Record high densities of larval fish were observed at most sites in 1988, and total larval species richness was second highest of recent years. A record total 84 species of adult/juvenile fishes were collected throughout the river. Record number of species were collected at five of six plant sites; likewise total abundance of fishes was relatively high at all sites. Spatial differences in fish abundance/biomass were not consistent between upstream/downstream sites at individual plant sites. Drought conditions likely caused displacement of some fish species from inland waters into the Ohio River.

Key Words: Ohio River, Drought, Larval fish, Adult fish, Macroinvertebrates, Thermal effects.

Introduction

The Ohio River Ecological Research Program is a long-term study of aquatic life near once-through cooled power plants on the Ohio River. The purpose of the Program is to: (1) assess potential effects of wastewater discharges (principally once-through cooling water) on nearby aquatic communities; (2) define factors influencing spatial and temporal patterns of biological parameters; and (3) provide inferences on the status of Ohio River water quality based on biological parameters. As a continuation of the Program, biological and water quality data were collected at six coal-fired generating stations on the Ohio River during 1988: Ohio Edison Company's W. H. Sammis Plant (River Mile 54), Ohio Power Company's Cardinal Plant (RM 76.7), Ohio Valley Electric Corporation's Kyger Creek Plant (RM 260), Cincinnati Gas & Electric Company's W. C. Beckjord Plant (RM 453), Indiana Michigan Power Company's Tanners Creek Plant (RM 494), and Tennessee Valley Authority's Shawnee Plant (RM 946). Macroinvertebrates were collected near three plant sites (Cardinal, Kyger Creek, Tanners Creek Plant) whereas ichthyoplankton and juvenile/adult fishes were collected at all plant sites.

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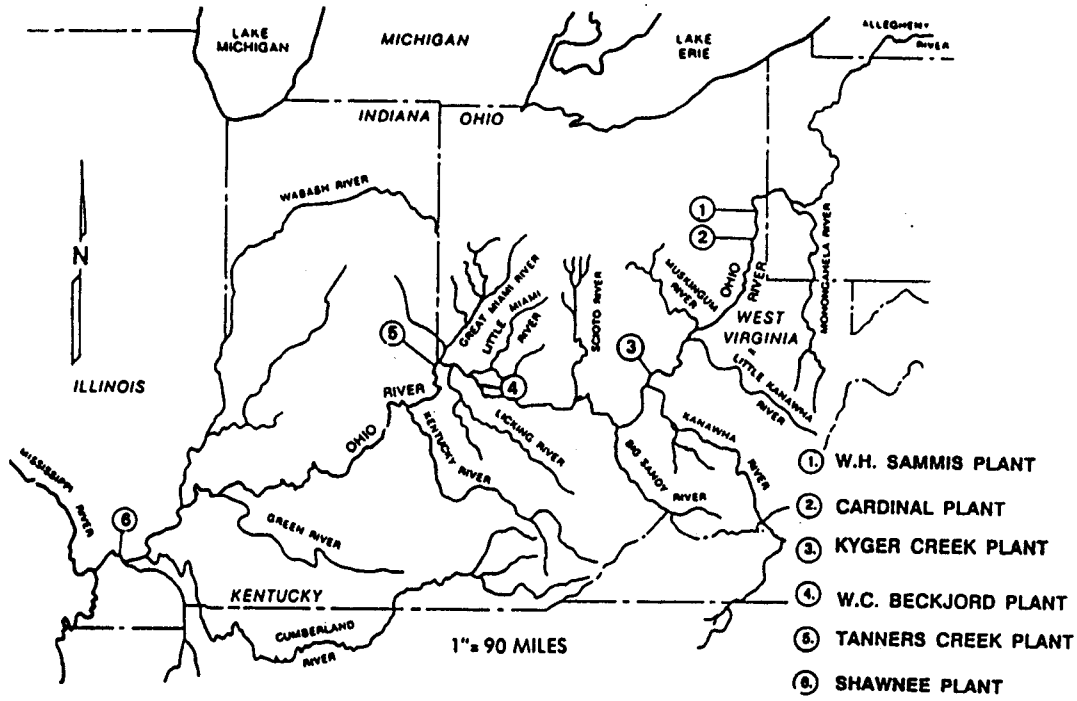

Figure 1. Location of power plant study sites for 1988 Ohio River Ecological Research Program.

During 1988 the Ohio River experienced two perturbations that, collectively, had the potential to cause long-term effects on the ecology of the river. On January 2, 1988 the Ashland Oil Company's Floreffe, Pennsylvania terminal had a release of approximately 750,000 gallons of crude oil into the Monongahela River which soon entered the upper Ohio River. Though long-term effects on the aquatic ecology of the upper river may never be determined, immediate and short-term impacts were generally less than expected.

The second perturbation experienced during 1988 was a prolonged drought. Low rainfall, elevated ambient air and water temperatures, and reduced flow rate all combined to produce potentially critical conditions in the Ohio River, and more crucially, in inland rivers and streams. During the anomalous meterological and hydrological conditions observed in summer 1988 the potential for deleterious power plant effects (e.g., once-through cooling water effects) was considerably increased. Because regulatory agencies issue permits for wastewater discharges based on protection of uses during critical low flows, results of biological monitoring during 1988 were crucial in providing data on the responses of aquatic communities to "worst-case" point source exposure. Likewise, biological monitoring during 1988 enabled dischargers and regulatory agencies the opportunity to assess the appropriateness of temperature criteria variances for Ohio River facilities allowed under Section 316(a) of the Clean Water Act.

Methods and Materials

Water quality, macroinvertebrate, ichthyoplankton, and adult/juvenile fish data were collected at six coal-fired power plant sites on the Ohio River during April through September, 1988. All sampling was conducted by a consultant, Environ-

mental Science and Engineering, Inc. A longitudinal distance of 1,435 km (892 miles) separated the uppermost plant site (Sammis Plant; RM 54) and the furthest downstream site (TVA's Shawnee Plant; RM 946) (Fig. 1). The six plant sites encompass three distinct ecoregions within the Ohio River basin (Western Allegheny Plateau, Interior Plateau, and Interior River Lowland). The boundaries of these ecoregions approximate the traditional geographic delineation of upper, middle, and lower segments of the Ohio River (Pearson and Krumholz 1984, Omernik 1987) A brief description of methods and material for all sampling is given below. Detailed descriptions are given in ESE (1989).

Physicochemical and Flow Measurements
Two or more routine water quality variables (dissolved oxygen, water temperature, conductivity, Secchi disk depth) were measured during all sampling dates at all stations. During weekly ichthyoplankton collections dissolved oxygen and water temperature were measured at stations upstream of power plants (i.e., ambient measurements). All other variables were measured during ichthyoplankton beach seine sampling (semi-monthly) and adult fish sampling (once during May, July, and September).

River flow data were obtained from U.S. Army Corps of Engineers measurements at the following locations: New Cumberland Lock and Dam (Sammis Plant), Pike Island Lock and Dam (Cardinal Plant), Gallipolis Lock and Dam (Kyger Creek Plant), Meldahl Lock and Dam (Beckjord Plant), Markland Lock and Dam (Tanners Creek Plant), and Smithland Dam (Shawnee Plant). River stage data were also obtained, but river stage varied only slightly during summer and fall 1988.

Macroinvertebrates
Macroinvertebrates were sampled at three plant sites (Cardinal Plant, Kyger Creek Plant, and Tanners Creek Plant) during two seasonal surveys. Organisms were collected at two stations using Hester-Dendy artificial substrate samplers and ponar grabs. Sampling stations were located just upstream of the power plant and between 250-1,000 meters downstream of the once-through cooling water discharge. At each station, five replicate Hester-Dendy's were set. Three replicate ponar grabs were taken at the time of Hester-Dendy retrieval.

Two seasonal (temporal) collections of macroinvertebrates were taken at each station. The first colonization period was during mid-May through mid-June and the second period was during mid-July to mid-August.

Ichthyoplankton
Ichthyoplankton (larval fish and eggs) were sampled at all plant sites from April 19 through August 25 using plankton nets and a bag seine. Nightime ichthyoplankton tows (using 500 u mesh nets having a 1-meter diameter mouth) were taken weekly at two transects upstream of all power plants. Duplicate surface tows and replicate bottom tows were taken at each transect, with a minimum of 50 m^3 water sampled for each tow. A total of 864 ichthyoplankton tow samples were collected in 1988. Bag seine samples were taken weekly from mid-April through July and once in August at all plant sites. A 560 u bag seine was used to sample larval fishes in shallow littoral areas at three stations along the plant shore. A total of 162 beach seine samples were collected.

Adult and Juvenile Fish
Adult and juvenile fishes were sampled using electrofishing, seining, trawling, hoop netting, and gill netting gear. Fishes were sampled during three seasonal surveys (May, July and September) at six stations per plant site. Three stations were located upstream of the plants and three were located downstream of the once-through cooling discharge. Details on field and laboratory processing for all methods are given in ESE (1989).

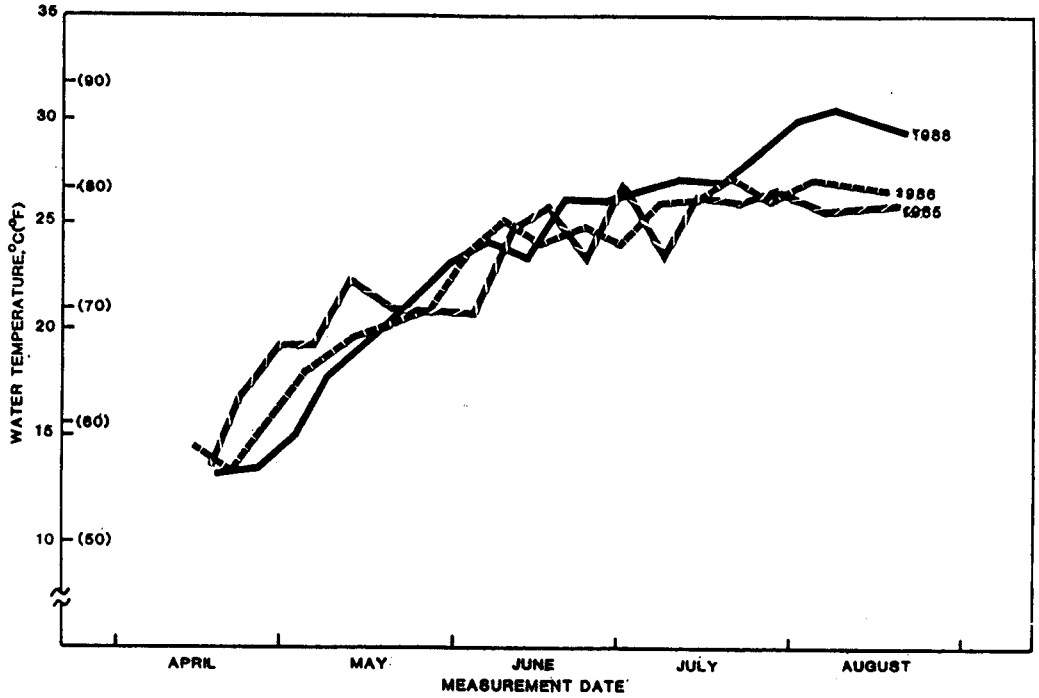

Figure 2. Ambient water temperature measurements taken upstream of Kyger Creek Plant during 1988, 1986 and 1985. Measurements were taken during weekly ichthyoplankton tows.

Results

Physicochemical and Flow Rate

In 1988, ambient water temperatures in the Ohio River approached historical mean values during the months of May and June. Ambient temperatures near 19°C have typically been associated with high densities of dominant larval fishes (gizzard shad, freshwater drum, carp, and carpsucker/buffalo) during previous years.

During 1988 temperatures near 19°C occurred during the week of May 16 in the upper Ohio River and during the week of May 9 in the middle and lower Ohio River, a trend observed in several previous years. Ambient water temperatures during July and August (the months following spawning for several species), however, were higher than historical means at all plant sites. As a site-specific example, July and August water temperatures upstream of Kyger Creek Plant were considerably higher than recent previous years, and temperatures exceeded 30°C during all measurements in August (Fig. 2).

During August at all plant sites, ambient temperatures exceeded maximum allowable stream temperatures as established by ORSANCO (ORSANCO 1987). At Shawnee Plant, ambient temperatures exceeded maximum ORSANCO criteria during several months. These observations indicate that ORSANCO temperature criteria were not derived to reflect anomalous meterological and hydrological conditions, and that generic temperature criteria for the upper, middle, and lower Ohio River may not be appropriate due to differing ambient temperature regimes in the lower and upper sections.

Dissolved oxygen (DO) concentrations were near saturation during all sampling occasions at all sites. The lowest DO concentration recorded during 1988 was 6.0 mg/L downstream of

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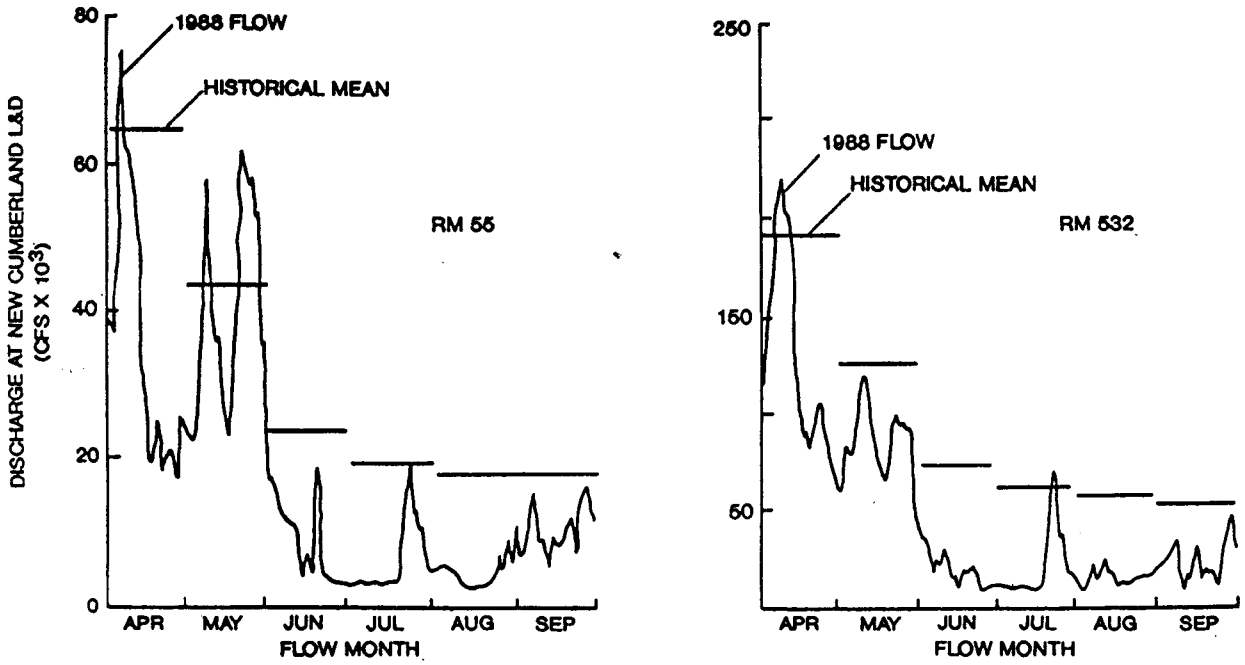

Figure 3. Flow rate measured at New Cumberland Lock and Dam (RM 55) (left) and Markland Lock and Dam (RM 532) (right), April through September, 1988. Historical mean flows indicated by horizontal line for each month.

Kyger Creek Plant in July. Upstream concentrations were just slightly higher on this date, however, averaging 6.4 mg/L. In general, concentrations in the Ohio River were not limiting during 1988 and downstream sites influenced by cooling water discharges at all plants had similar or only slightly lower DO levels.

Flow rates measured at proximal lock and dam locations indicated markedly lower flows in 1988 compared to historical means. Throughout the river, flow rate was highest in spring (April and May), lowest in late June and August, and somewhat higher in September compared to August. The magnitude of deviation of 1988 flows from historical means was related to longitude, and tended to increase downstream. Flow rates near Sammis Plant (RM 54) were below historical means during June through September whereas flow rates near Shawnee Plant (RM 946) were well below historical means for all months studied (April through September); deviation of flow rates from historical means near Tanners Creek Plant (RM 495) was intermediate compared to previously mentioned plant sites (Figs. 3, 4).

Benthic Macroinvertebrates

Combined Hester-Dendy and ponar grab collections (for both surveys) showed total macroinvertebrate densities of 1,459/m^2 at Cardinal Plant and 1,381/m^2 at Tanners Creek. In contrast, combined ponar and Hester-Dendy samples from Kyger Crek Plant had a mean total density of 892/m2. Although a lower mean density was observed at Kyger Creek, the total number of taxa collected was similar at all plant sites (Table 1). The benthic community near Cardinal Plant was dominated by an oligochaete-amphipod complex. An

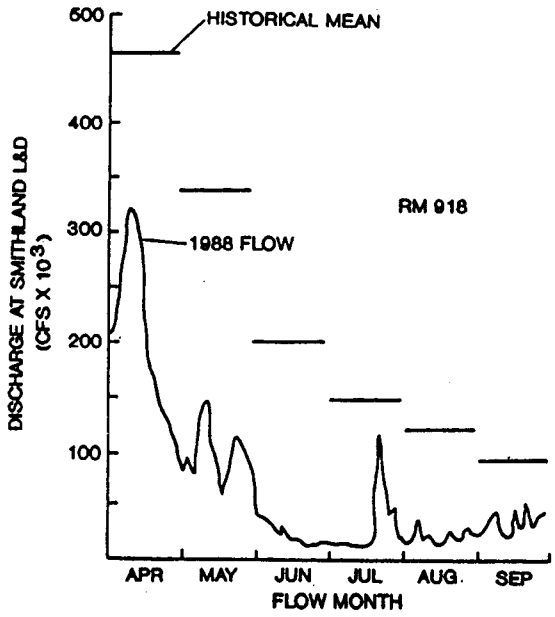

Figure 4. Flow rate measured at Smithland Lock and Dam (RM 918), April through September, 1988. Historical mean flow indicated by horizontal line for each month.

oligochaete-mollusk complex dominated at Kyger Creek plant whereas an oligochaete-amphipod-chironomid assemblage was numerically dominant near Tanners Creek Plant (Table 1).

Temporal variation in macroinvertebrate parameters between upstream and downstream stations was observed at all three plant sites. At Cardinal Plant, marcoinvertebrate parameters during the May-June Hester-Dendy survey suggested a more limited community at the downstream station. Upstream and downstream values (in parentheses) for number of taxa, total density (#/m2) and biotic index were 24(18), 1,199(569) and 4.19(4.18), repsectively. During the late summer survey, however, the upstream station showed a more limited community. Upstream and downstream values (in parentheses) for number of taxa, total density, and biotic index for the July-August survey were 17(20), 312(1,281), and 5.77(7.24).

A similar trend was observed at Kyger Creek Plant. During the first Hester-Dendy survey upstream and downstream values (in parentheses) for number of taxa, total density, and biotic index were 33(30), 665(460), and 4.36(6.18), respectively. For the July-August survey upstream and downstream values (in parentheses) for number of taxa, total density, and biotic index were 24(33), 618(801), and 7.07(6.66), respectivley. These data not only confirm the expected temporal variability of macroinvertebrate parameters in the Ohio River, but indicate that downstream benthic communities were not consistently less diverse and abundant than upstream communities.

At all plant sites, Hester-Dendy samples had consistently greater number of taxa compared to Ponar grab samples. This trend ws observed for both seasonal surveys. These results suggest that substrate characteristics were more limiting than potential water quality effects at all sites studied.

The collection of one macroinvertebrate species in 1988 deserves special mention. Medusae of the freshwater jellyfish (Craspedacusta sowerbyi) were collected in ichthyoplankton tows at all six plant sites. The presence of this species indicates low flow conditions in the Ohio River as this invertebrate is usually restricted to lentic systems (Pennak, 1978).

Ichthyoplankton

For combined tow and beach seine samples at all sites, a total of 492,365 larvae and eggs were collected during 1988. Seventy taxa (including 52 species) representing 13 taxonomic families were identified. This was the second highest total taxa since larval fishes were first collected in 1976. Taxa richness was highest from Shawnee Plant collections, where 47 taxa (34 species) were collected in 1988. Taxa richness was lowest at Tanners Creek Plant (32 taxa, 24 species) and Kyger Creek Plant (33 taxa, 25 species).

Table 1. Benthic macroinvertebrate sampling results at three Ohio River plant locations, May-August, 1988. Values given are for combined upstream and downstream stations and combined May-June and July-August surveys.

Macroinvertebrate Parameter	Cardinal RM 77	Kyger Creek RM 260	Tanner Creek RM 495
Mean density (Hester-Dendy)[a]	840	636	2,769
Mean density (ponar)[a]	2,077	1,148	954
Mean density (combined methods)[a]	1,459	892	1381
Most abundant taxa (combined methods)[b]	Imm. tubificids Gammarus sp. Aulodrilus sp. Limnodrilus sp. Dugesia sp.	Imm. tubificids Limnodrilus sp. Corbicula sp. Gammarus sp. Glyptotendipes sp.	Imm.tubificids Gammarus sp. Glyptotendipes sp. Cricotopus sp. Cyrnellus sp.
Total taxa	54	63	62
Shannon-Wiener diversity	2.49	3.14	3.24
Biotic index	6.18	6.49	7.40

a Densities given as #/m2.
b Most abundant taxa listed in descending order of relative abundance.

Taxa that were abundant at all plant sites included gizzard shad, carp, emerald shiner, carpsucker/buffalo, Morone sp./white bass, Lepomis sp., and freshwater drum. Spotfin shiner, sand shiner, mimic shiner, bluntnose minnow, channel catfish, logperch, and walleye were collected at all plant sites but in fewer numbers. These ubiquitous species have extensive geographic ranges and many can tolerate a wide range of water quality/habitat conditions.

Several taxa were restricted to specific regions of the Ohio River. Larval fishes collected exclusively in the upper ecoregion (Western Allegheny Plateau) were northern hog sucker, shorthead redhorse, rock bass, banded darter, and yellow perch. Larval species restricted to the middle and lower ecoregions included paddlefish, goldeye, speckled chub, bullhead minnow, striped bass, threadfin shad, blue sucker, blue catfish, and brindled madtom.

During 1988 larvae of four species were collected for the first time: pumpkinseed (RM 76), silver lamprey (RM 260), gravel chub (RM 453), and striped bass (three lower plant sites). The collection of a larval lamprey at Kyger Creek Plant was unexpected as ammocoetes of most lamprey species are typically confined to inland streams or rivers. The collection of this specimen may represent actual spawning in the Ohio River or displacement from streams having insufficient flow due to drought conditions.

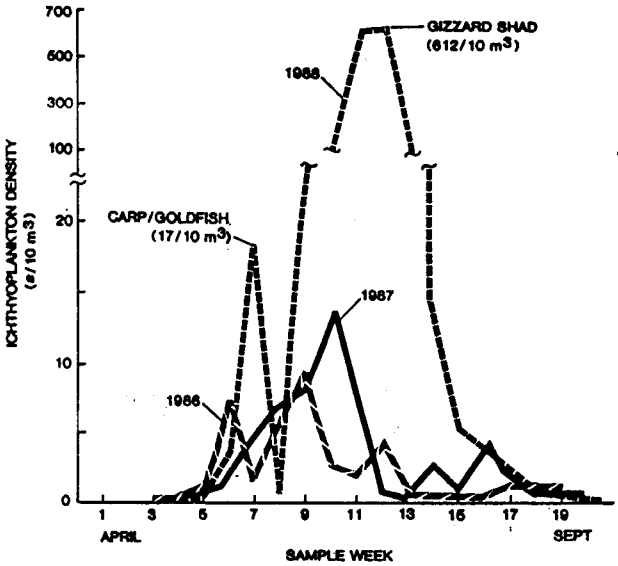

Figure 5. Weekly densities of ichthyoplankton sampled just upstream of W.H. Sammis Plant (RM 54), 1986-1988.

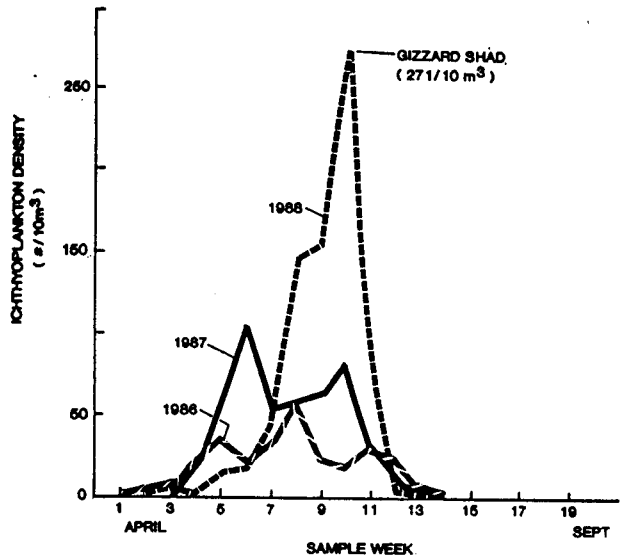

Figure 6. Weekly densities of ichthyoplankton sampled just upstream of Tanners Creek Plant (RM 495), 1986-1988.

Record high densities of ichthyoplankton were observed at five of six plant sites in 1988. Peak densities were highest at W. H. Sammis Plant (635 larvae/10 m3 on June 26) (Fig. 5). This peak density was the highest ichthyoplankton density observed in the history of the Program, and was comprised predominantly by gizzard shad larvae (612 larvae/10 m3).

Gizzard shad or combined herring taxa dominated the peak densities at all other plant sites. Gizzard shad comprised 98% of all larvae during peak densities at Tanners Creek Plant (Fig. 6), and herrings comprised 90% of all larvae during the peak density at Shawnee Plant (Fig. 7). Other taxa collected in considerably greater numbers during 1988 were carp, Morone sp., white bass, Lepomis sp., and Stizostedion sp.

In previous years, total mean density of ichthyoplankton was typically highest at middle or lower Ohio River plant sites. In 1988, however, total mean density was highest at W.H. Sammis Plant (upper river) and lowest at Beckjord Plant (middle river). The chance collection of numerous gizzard shad shortly after a major hatch near Sammis Plant is likely responsible for this observation.

Densities of ichthyoplankton in nearshore areas (beach seine collections) were highest at the two lower plant sites. Beach seine densities were highest at Shawnee Plant (mean density = 255/10 m3) and Tanners Creek Plant (mean density = 118/10 m3). Mean densities at other plant sites ranged between 23 - 70/10 m3.

Adult and Juvenile Fish

In 1988, a total of 90,710 individuals representing 94 taxa (84 species) were collected during adult and juvenile fish sampling. The 84 species collected in 1988 represents the highest species richness during the history of the Program. Forage species were numerically dominant throughout the river, as in previous years. Gizzard shad and emerald shiner accounted for 46% (41,638 individuals) and 27% (24,7470 individuals) of the total species catch, respectively. Channel

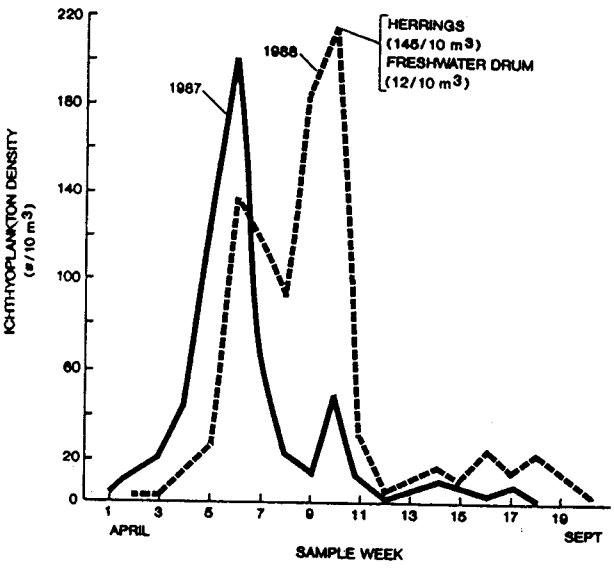

Figure 7. Weekly densities of ichthyoplankton sampled just upstream of Shawnee Plant (RM 946), 1987-1988.

catfish, white bass, bluegill, and freshwater drum were also abundant at all plant sites.

Species collected at plant sites located in the upper ecoregion only included brown trout, river chub, striped shiner, sand shiner, black redhorse, white sucker, rock bass, and several darter species. Paddlefish, shortnose gar, bowfin, threadfin shad, red shiner, and blue catfish were collected exclusively near the Shawnee Plant in 1988. Many of these region-specific collections have been documented in previous years. No longitudinal trends in species richness were evident during 1988, as in previous years. Species richness was highest at Sammis Plant (53 species) and Shawnee Plant (51 species). Species richness at other plant sites ranged from 39 to 47 species collected.

For all sites combined, seining was the most productive sampling gear with 51,400 individuals captured by seines in 1988. Electrofishing sampling resulted in the collection of 23,443 fishes, whereas gill netting and trawling each collected about 7,000 specimens. Hoop netting was the least productive sampling method (841 individuals). The relatively high catches in beach seines was due to utilization of near-shore littoral areas by several species, especially these using littoral zones for nursery areas.

Statistical analyses of total abundance and biomass data using ANOVA indicated significant temporal (i.e., seasonal) effects at all plant sites for two or more sampling methods. For example, gill netting and electrofishing in September produced higher catch rates than May and July samples at several plant sites. Seine collections produced higher catch rates in July at five of six plant sites.

In contrast, spatial (i.e., upstream versus downstream) effects were generally not observed during 1988. At Shawnee Plant, catch rates for gill netting and trawling were higher at upstream sites, whereas biomass of fishes was higher in electrofishing samples downstream of Kyger Creek Plant. Adult and juvenile fish sampling in 1988 indicated no trend of decreased catch rates at downstream sites. These results indicate that the abundance and biomass of fishes was similar upstream and downstream of the cooling water discharges, and potential thermal effects (expected to be exacerbated by low flow conditions) were not observed.

Discussion

Due to prolonged drought conditions, anomalous hydrological and physicochemical conditions were observed in the Ohio River during 1988. Elevated ambient temperatures and below normal flow rates appeared to profoundly influence the biological productivity of the entire river. The timing of elevated ambient temperatures appeared to be a crucial factor in promoting biological productivity, especially fish spawning success and larval survival. Water temperatures in June,

July and August were warmer than historical means at all plant sites. These are the months following spawning of many Ohio River fishes. Sustained high temperatures likely enhanced the early spawning of some species, promoted larval growth rates due to the increased abundance of phytoplankton or zooplankton, and favored the increased duration of spawning for some species. Increased larval survival resulted in higher than normal ichthyoplankton densities, as was observed with gizzard shad. Because the flushing rate of the Ohio River was reduced considerably in 1988, larvae of pelagic spawning fishes (e.g., gizzard shad, freshwater drum, skipjack herring) were very abundant and appeared to have high survival.

Comparison of 1988 benthic macroinvertebrate data with previous years (1981 and 1984; Geo-Marine 1982, Geo-Marine 1986) indicates that no major changes in species composition have occurred at upper and middle river plant sites. An increase in the number of taxa present in 1988 was observed at Kyger Creek and Tanners Creek Plants; taxa richness at Cardinal Plant was similar to the number of taxa collected in 1984. Increases in taxa richness, however, may be attributable to increased ability to identify some taxa.

Total densities of macroinvertebrates were generally higher in 1988 compared to previous years. In addition, biotic index scores have generally decreased since 1981 at Cardinal and Kyger Creek Plants, suggesting improved water quality at these sites due to the presence of less intolerant communities. In contrast, biotic index scores at Tanners Creek Plant have not changed markedly since 1981. In summary, benthic macroinverterbrate data collected during the Ohio River Ecological Research Program suggest improved water quality, especially at sites in the upper river. Reinvasion or extensions of numerous fish species in the upper section have been recently noted (Pearson and Pearson 1989). These trends are consistent with temporal patterns of chemical-specific parameters in the upper river that indicate improvements in water quality (Cavanaugh and Mitsch 1989).

Adult and juvenile fish sampling in 1988 indicated that the longitudinal distribution of Ohio River fishes is related to factors associated with zoogeography, flow regime, and environmental tolerance. These and other factors have been discussed previously (Reash and Van Hassel 1988; Van Hassel et al. 1988). At plant-specific locations the abundance, biomass, and species richness of adult/juvenile fishes was not adversely affected by power plant discharges in 1988. Rather, the combination of habitat, water quality, and flow effects appear to be more important influences as significant temporal differences in fish community parameters were common, whereas upstream/downstream differences were rarely observed.

Acknowledgments

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Literature Cited

Cavanaugh, T.M. and W.J. Mitsch. 1989. Water quality trends of the upper Ohio River from 1977 to 1987. Ohio Journal of Science 89:153-163.

ESE (Environmental Science and Engineering, Inc.). 1989. 1988 Ohio River Ecological Research Program. Final Report. Environmental Science and Engineering, Inc., St. Louis, Missouri.

Geo-Marine, Inc. 1982. 1981 Ohio River Ecological Research Program. Adult and juvenile fish, ichthyoplankton and benthic macroinvertebrate studies. Geo-Marine, Inc., Plano, Texas.

Geo-Marine, Inc. 1986. 1984 Ohio River Ecological Research Program. Adult and juvenile fish, ichthyoplankton, and macroinvertebrate studies. Geo-Marine, Inc., Plano, Texas.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

Pearson, W.D. and L.A. Krumholz. 1984. Distribution and status of Ohio River fishes. Oak Ridge National Laboratory Publication No. ORNL/Sub/79-7831/1. Oak Ridge, Tennessee.

Pearson, W.D. and B.J. Pearson. 1989. Fishes of the Ohio River. Ohio Journal of Science 89:181-187.

Pennak, R.W. 1978. Fresh-water invertebrates of the United States. 2nd Edition. John Wiley & Sons, Inc., New York.

ORSANCO (Ohio River Valley Water Sanitation Commission). 1987. Pollution control standards, 1987 revision. Ohio River Valley Sanitation Commission, Cincinnati, Ohio.

Reash, R.J. and J.H. Van Hassel. 1988. Distribution of upper and middle Ohio River fishes, 1973-1985: II. Influence of zoogeographic and physicochemical tolerance factors. Journal of Freshwater Ecology 4:459-476.

Van Hassel, J.H., R.J. Reash, H.W. Brown, J.L. Thomas and R.C. Mathews, Jr. 1988. Distribution of upper and middle Ohio River fishes, 1973-1985: I. Associations with water quality and ecological variables. Journal of Freshwater Ecology 4:441-458.